M.O. 533 AIR MINISTRY

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ESKDALEMUIR OBSERVATORY

By J. CRICHTON, M.A., B.Sc., F.R.S.E.

Early in the present century the extension westwards from London of the tramway system caused so much artificial magnetic disburbance at Kew, that it was decided to establish another observatory where, as far as could be foreseen, magnetic recording would not be interfered with in the same way. A committee of the Royal Society selected Eskdalemuir for this purpose; work was put in hand, and the Observatory opened in 1908. So far no encroachment by artificial disturbance has taken place.

The Observatory lies in the north-east corner of Dumfriesshire, near the source of the Black Esk and the White Esk, streams which later join and flow on to the Solway Firth as the River Esk. The site, about 11 acres in extent, is on a rising shoulder of moorland, sloping from north-west to south-east, some 17 miles from Langholm and 18 miles from Lockerbie. The general sweep of the countryside may be gleaned from the photograph facing p. 344, taken looking westwards from an aeroplane flying at a height of 500 ft. In the top right-hand corner of the photograph may be seen "Ettrick Pen", a hill four or five miles distant and rising to 2,259 ft. above mean sea level; the Observatory itself is about 800 ft. above mean sea level.

From the beginning the principal functions of the Observatory have been the study of (*a*) terrestrial magnetism, (*b*) meteorology, (*c*) atmospheric electricity, and (*d*) seismology (until 1925); and for this purpose instrumental equipment has always been of high quality. In 1925 the seismological equipment was transferred to Kew Observatory.

The work in terrestrial magnetism consists largely of the maintenance and study of continuous records of the earth's magnetic field. The records or magnetograms are photographic and are obtained from three sets of magnetographs, namely a slow-run la Cour set of high sensitivity with a traversing rate of 15 mm./hr., a quick-run la Cour set, also of high sensitivity, with a traversing rate of 15 mm./5 min. and a Kew Adie set of low sensitivity with a traversing rate of 15 mm./hr. The second of these sets enables the times of incidence of various movements to be more accurately determined than with the standard set and the last, owing to its low sensitivity, is of value during very disturbed magnetic conditions, permitting large movements being recorded and easily followed. The elements recorded in each set are horizontal force (H), declination (D) and vertical force (V).

The magnetographs are located in a large underground house, the entrance to which can be seen clearly near the centre of the grounds in the aerial photograph. It is constructed of non-magnetic material and consists of two chambers with encircling corridors, each chamber being about 29 ft. long, 24 ft. broad and 10 ft. high. This form of housing the magnetographs was adopted with a view to minimizing temperature variations, and from the outset the daily temperature variations were almost completely eliminated. It was not until the introduction of thermostatically controlled electrical radiators in 1936 that the seasonal temperature variations were brought under control. Prior to the introduction of electricity, paraffin oil or acetylene lamps were used for illuminating purposes and these gave rise to problems of condensation and ventilation.

Magnetographs are delicate instruments and great care must be exercised in determining their scale values and the values of the elements they record. The scale values are determined at the instruments themselves, while the values of the elements are determined in what are known as "absolute huts". The huts, like the underground house, are of non-magnetic construction and the two at Eskdalemuir are located, as far away as possible from all other buildings, at the northern end of the enclosure (see photograph). The hut in general use is that in the north-east corner and the instruments employed are seen in the photograph facing p. 345; on the right is the Kew magnetometer used in the determination of D and occasionally H, in the centre the Schuster-Smith coil, for H, and on the left the Schulze dip inductor, for I (inclination) and thence V from the relation, $V = H \tan I$. Recently this standardizing equipment has been increased by the addition of three quartz-fibre horizontal force magnetometers (Q.H.M.'s) and a vertical force balance magnetometer (B.M.Z.), designed and constructed in Denmark. The Q.H.M.'s and the B.M.Z. are easily transportable and will be used for the comparison of Eskdalemuir standards with those of other observatories.

The hourly and other values measured from the standardized magnetograph records are tabulated, summarized and discussed. The results of such work will be found in the *Observatories' Year Book*. With the passage of time the secular variation of the elements becomes important—for example, since the opening of the Observatory D, at Eskdalemuir, has changed almost at a uniform rate from just over 18°W. to between 11° and 12°W. Hourly values of magnetic declination are published weekly in the *Colliery Guardian* and the *Iron and Coal Trades Review*, this service, which has been in operation since 1927, being for mining surveyors. Alongside the Eskdalemuir data in these journals the corresponding data are given for Greenwich (Abinger). Mining surveyors and others interested are also supplied at a nominal charge with contact prints of the original magnetic records. From time to time magnetic information is passed to the National Physical Laboratory, the Radio Research Board, various University and allied bodies, while the Astronomer Royal notifies the Observatory of the passage of large and active sunspots across the surface of the sun, these not infrequently being accompanied by terrestrial magnetic disturbance.

For a period of years, in addition to the above magnetic work, experimental work was carried out, intermittently, on the rate of change of vertical magnetic force. This was done, on an open time-scale, by photographing the indications of a galvanometer conneted to a large loop laid horizontally on the moor outside the Observatory grounds.

Turning now to the meteorological side of the routine, the work here is that of a first order station. At the outset the principal tasks were chiefly recording, tabulating and analysing, but, after the transfer of the control of the Observatory in 1910 from the National Physical Laboratory to the Meteorological Office, the meteorological routine has been gradually extended. Nowadays, telegraphic reports are sent to the Central Forecasting Office ten times a day (seven on Sundays).

In addition to the normal eye-reading and autographic equipment to be found at such a station, there are a photographic barograph and a photographic thermograph (wet-bulb and dry-bulb thermometers). The photographic records, as in the case of the magnetograms, require to be standardized; for this purpose control readings are taken three times each day. In case of failure of photographic records, pen records are available. There is also a Hellmann-Fuess snow-gauge for measuring the amount and rate of snowfall and a Jardi rate of rainfall recorder. A night-sky recorder is maintained in operation and, on behalf of the Department of Scientific and Industrial Research, an atmospheric-pollution recorder. For a period, observations of atmospheric ozone were made with a Dobson ozone spectrophotometer. Equipment for measuring direct and diffuse short-wave radiation on a horizontal surface from sun and sky has been installed.

In atmospheric electricity a continuous photographic record of atmospheric electrical potential is maintained and standardized by means of a quadrant electrometer connected to a polonium collector. Before the polonium collector came into use, a collector of the Kelvin water-dropper type was in use. The meteorological and atmospheric electrical observations, tabulations and observed results are published in the *Observatories' Year Book*.

The buildings at the southern edge of the enclosure (on left-hand side of aerial photograph) are Rayleigh House, the main office block and Schuster House. Just to the outside of the enclosure are Shaw and Glazebrook Houses and to the north-west of these, but inside the enclosure, lie the garage, battery and charging house and the handyman's cottage. The main house names commemorate the distinguished scientists associated with the foundation and early days of the Observatory. As may be gathered from the photograph, the Observatory forms an isolated community on its own. Such isolation, however, presents its own difficulties with staff—the accommodation is strictly limited and it has always been difficult to keep the work within the capacity of the staff. It may be said that those who have served at the Observatory look back with something akin to affection to the days they spent amongst the hills. Amongst their number may be listed three Fellows of the Royal Society, and, of the present staff of the Meteorological Office, two Deputy Directors as well as many other senior members of the staff. The isolation, in the early days, when motor transport was not available, did not seem so great as it does now—this may appear a paradox, but as recreation becomes ever more communal in character, the individual tends to lose his ability for private amusement and study. However, the isolation has its advantages—did not a prophet in the Old Testament find advantage in withdrawing occasionally from political life and musing under a juniper bush? Former members of the staff will be pleased to hear that Miss K. Mackay and Mr. W. J. Hogg are still at the Observatory.

No note about the Observatory and its work could be complete without reference to the late Mr. John B. Beck. Mr. Beck joined the staff as a boy clerk in May 1913, and, apart from a period in the Forces in the first world war, served continuously until the time of his death on March 8, 1950. Mr. Beck will be remembered with affection by all who came in contact with him.

WINTER GALES AND HEBRIDEAN SHIPPING

By D. L. CHAMPION

In a letter written last February, Capt. J. MacInnes, M.B.E., Master of the R.M.S. *Lochness* (777 tons) plying between Oban and the Outer Hebrides, mentioned that the gales of the winter 1948–49 were among the most severe and persistent he had experienced in Hebridean waters. The storminess of this particular season is also referred to in a paper on "The Parish of Barra" by Peggie M. Hobson in the *Royal Scottish Geographical Journal*, in which she states the winter of 1948–49 was "the wildest for many years in the Hebrides".

Reports from the *Oban Times*, summarized below, indicate the severity of these gales and their effect on shipping.

Saturday, January 1. A heavy gale rose on Monday, sweeping the entire west coast. The mailboat *Lochness* was unable to call at the islands of Tiree and Coll. The steam trawler *Commiles* ran ashore 100 yd. south of Kyle pier on Tuesday evening. A light-keeper at Skerryvore was taken ill on Monday, but the lighthouse tender *Hesperus* with a relief keeper was forced to take shelter at Bunessan owing to the severity of the gale and could not proceed until Friday.

Saturday, January 22. One of the worst gales yet experienced this winter. West-coast mailboats were forced to miss several calls. Trawler *Brecon Bank* driven ashore near Maiden Island, Oban.

Saturday, January 29. Stormy seas prevented the mailboat *Lochness* from making any landing at Barra on Monday. On Wednesday another attempt was made, but the vessel was forced to remain at anchor off the island overnight. The gale continued on Thursday, but on Friday morning the vessel was able to make the pier. On Tuesday she was unable to make her weekly call at Colonsay because of the stormy winds. The island of Eigg was cut off by storms all the week.

Saturday, February 26. The fishing boat *Alliance* was driven aground near Drimnin, in the Sound of Mull. The mailboat *Lochness* on her inward run was forced to miss two calls and to abandon her weekly run to Colonsay. The steamer *Loch Seaforth* was unable to reach Kyle pier and was forced to remain at anchor outside. The crew of the *Lochearn*, which arrived 1½ hr. late from Harris on Tuesday, said it had been their worst crossing of the Minch for many years.

It was thought that the gales of this winter merited further investigation, and accordingly available data were extrated from the *Monthly Weather Report* for the following stations : Cape Wrath (8 yr.), Duntulm, Stornoway, Tiree and Oban (13 yr.), and, in addition, reports from Barra and Benbecula were available for the past six winters.

The map, Fig. 1, shows the geographical situation of these stations, against which are shown three sets of figures. The figure in the circle is the average number of winter gales (December to February inclusive), the larger type upper figure is the number experienced in the winter of 1948–49, and the

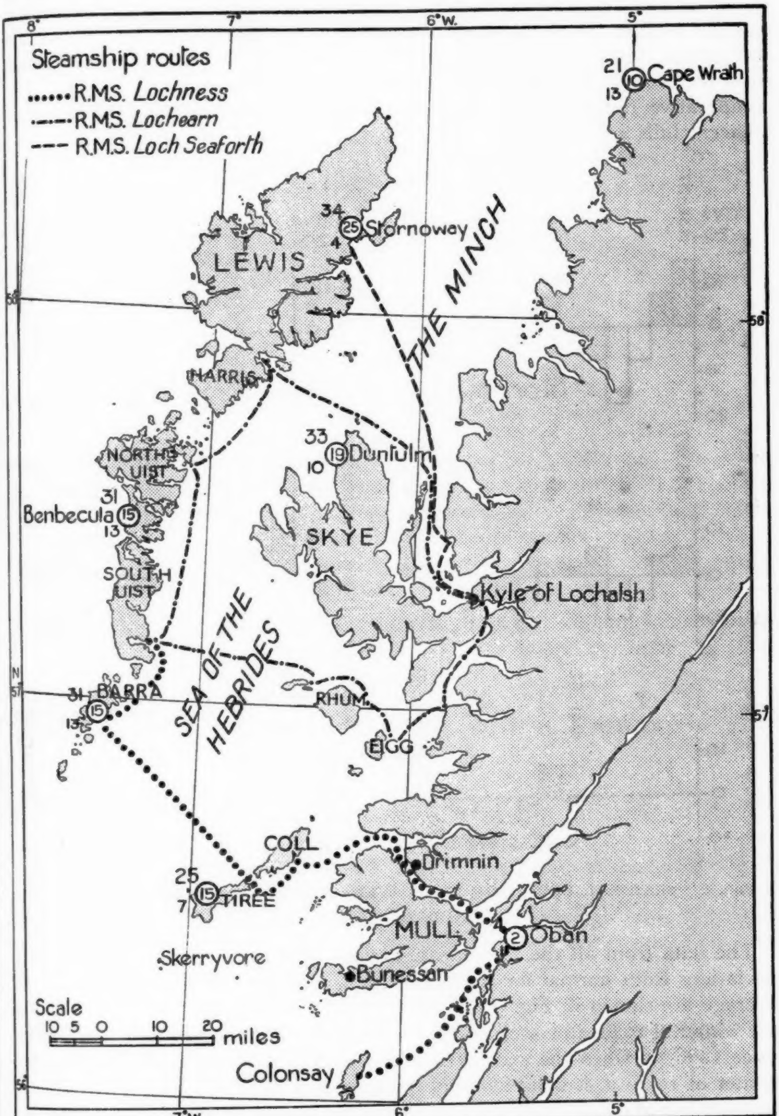


FIG. 1—GALES IN THE HEBRIDES

lower figure gives the number of gales observed in January 1949. The routes of the respective mail steamers are also indicated.

The seasonal deviation from the average number of gales at the above stations is shown in Fig. 2. It will be seen that at Stornoway the excess of days of gale in 1948–49 was the highest since the winter of 1942–43, at Duntulm it was the highest for the past 13 winters, and at Cape Wrath and Benbecula the highest in the past eight years and six years respectively. At Tiree, apart from the winter of 1946–47, it was the stormiest season since 1936–37. The comparative freedom from gales at Oban, due to the shelter afforded by adjacent hills and islands is well marked.

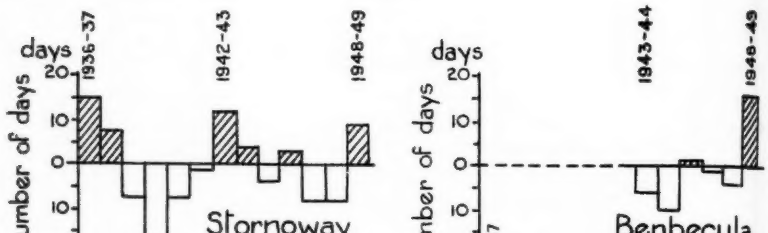


FIG. 2—SEASONAL DEVIATION FROM AVERAGE NUMBER OF DAYS WITH GALE AT INDIVIDUAL STATIONS

The data from all the Hebridean stations have been summarized, and the deviations from normal for the whole area, expressed as a percentage of the average are shown in Fig. 3 for the past thirteen winters. The storminess of the winter of 1948–49 is well marked with an excess of 67 per cent., the highest since 1936–37 when the excess reached 95 per cent. In marked contrast, the winter of 1939–40 is conspicuously quiet, with a deficiency of 69 per cent. in the number of gales.

When one considers how much life in the Hebrides depends on supplies and mails from the mainland, carried by the relatively small mail steamers, the

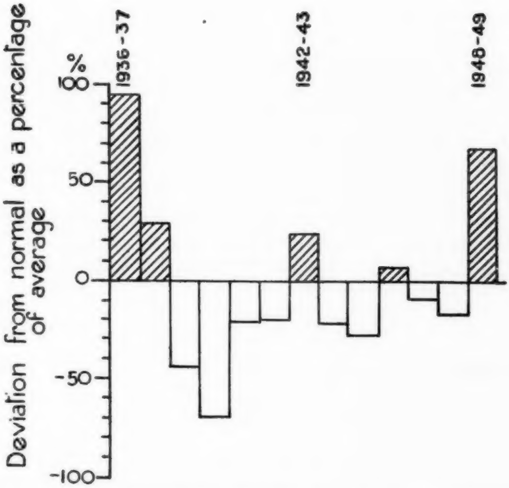


FIG. 3—PERCENTAGE DEVIATION FROM AVERAGE NUMBER OF DAYS WITH GALE AT ALL STATIONS

R.M.S. *Lochness*, *Lochearn* and *Loch Seaforth* (all less than 1,000 tons) the effects of prolonged gales in delaying these ships is not to be disregarded. The route of the R.M.S. *Lochness* in particular is very exposed to the high seas associated with south-westerly gales, especially so on the fifty-miles crossing between Tiree and Barra, where waves exceeding 30 ft. in height are sometimes encountered. The effect on the little ship can well be imagined.

From the above it will be seen that the winter of 1948–49, and January 1949 in particular, will be long remembered for the severity and persistence of gales in the Hebrides.

NOTES ON THE TEMPERATURE AT WHICH RADIATION FOG FORMS

By J. BRIGGS, B.A.

It is well known that radiation fog forms more readily in stable air than in unstable air. The depression of air temperature, below the evening dew point, prior to fog formation appears to bear some relation to the initial degree of stability or instability. In summer fog also appears to develop more easily in air advected from the sea than in air over land, although both may have the same initial dew point. Fog forms more readily over wet ground than over dry, especially if rain immediately precedes sunset.

It is apparent from these considerations that the forecasting of fog is not possible on the basis of screen observations alone. Therefore it was decided to investigate the relationship between fog formation and the temperature and humidity observations up to a height of approximately 5,000 ft.

The observations used were those made at Mildenhall from August 1940 to October 1941, the upper air observations of temperature and humidity being made by aircraft. Until the middle of June 1941 two ascents were made each

day, in the morning and in the afternoon; these were taken as representing conditions after and before the radiative cooling. From June onwards three ascents were made each day; morning, midday and evening; during this period the evening ascent was taken as representative of pre-cooling conditions, although in some cases cooling was already showing near the surface and corrections had to be applied. The normal screen observations at Mildenhall served as a basis for estimating the fog point (i.e. that temperature at which fog became or was likely to have become fairly general over the adjacent area). This definition of the fog point excludes the very localized fog which forms in valleys and sheltered places on almost any radiation night. Observations from other stations in East Anglia served as a check of the Mildenhall observations.

Mildenhall can be regarded as an "average" station as regards liability for fog and the area around is relatively free from smoke pollution.

Results obtained.—During the period mentioned there were 43 occasions when radiation conditions were considered to have occurred and when the surface wind was Beaufort force 2 or less for at least two successive observations.

Table I shows the average value of the water-vapour content of the air; any obvious cases of a change of air-mass between the afternoon and morning ascents were excluded.

TABLE I—AVERAGE WATER CONTENT OF THE AIR

	Water-vapour content at heights				
	Surface	1,000 ft.	950 mb.	900 mb.	850 mb.
	grammes per kilogramme				
Afternoon (or evening) ...	7·6	7·0	6·7	6·3	5·3
Following morning	5·8	5·9	5·7	5·6	4·9

Individual examples were next examined to determine the fog point. To show the effects of varying lapse rate and humidity, Table II was prepared. This shows the number of occasions when the fog point corresponded to the potential dew point at a certain level more closely than to the potential dew point of any lower level. The potential dew point for a certain level is defined as the dew point which the air, originally at that level, would have if it were lowered adiabatically to the surface level.

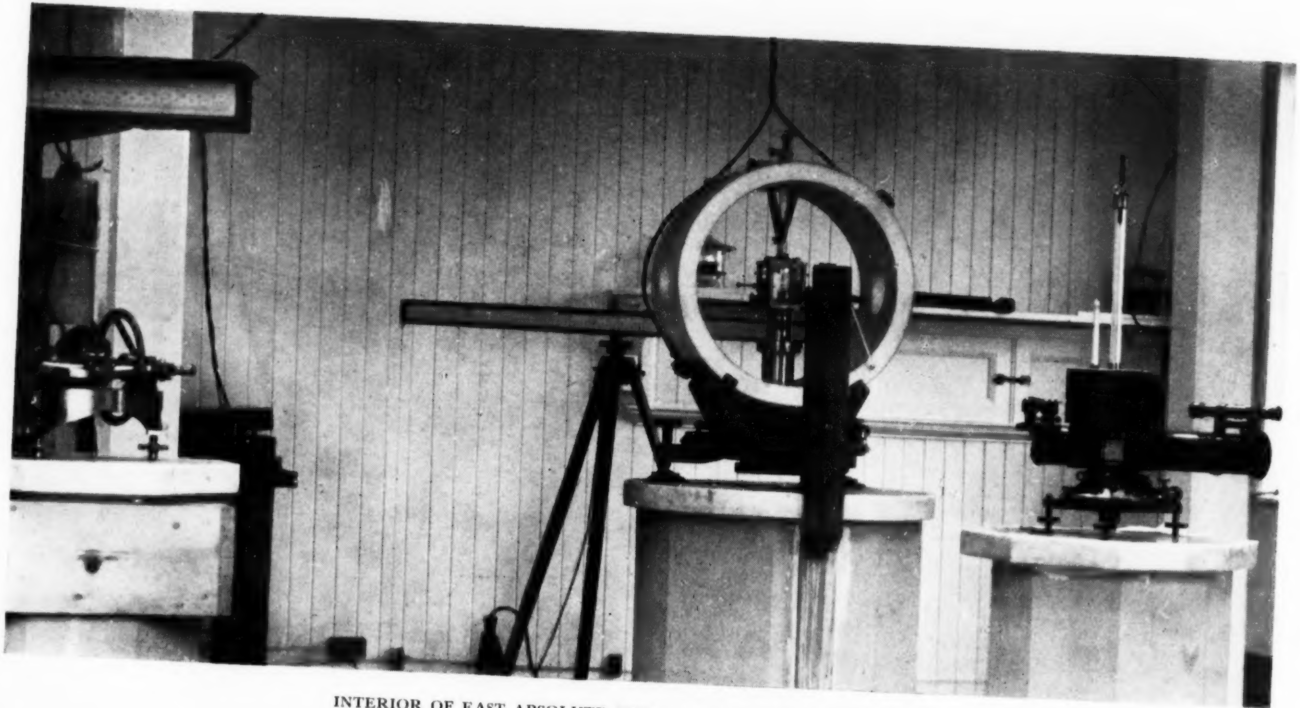
TABLE II—NUMBER OF OCCASIONS WHEN FOG POINT CORRESPONDED MORE CLOSELY TO THE POTENTIAL DEW POINT AT A CERTAIN LEVEL THAN AT ANY LOWER LEVEL

Initial lapse rate	Potential dew point between: Surface and 1,000 ft.	1,000 ft. and 950 mb.	950 mb. and 900 mb.	900 mb. and 850 mb.
°F./1,000 ft.				
	(a) All cases			
<3	3	3	1	4
3–4	1	1	3	3
>4	1	1	2	20
	(b) All cases except with hoar frost or wet ground at start of cooling			
<3	3	2	1	1
3–4	0	1	2	2
>4	0	0	1	13

[To face p. 344

AERIAL VIEW OF ESKDALEMUIR OBSERVATORY
(see p. 337)

To face p. 345]



INTERIOR OF EAST ABSOLUTE HUT, ESKDALEMUIR OBSERVATORY

Left to right:—Schulze dip inductor, Schuster-Smith coil, Kew magnetometer (see p. 338)

For reasons discussed later it was decided to eliminate those occasions on which hoar frost occurred or when the ground was wet at the start of cooling, or when there was an initial inversion of the humidity lapse; the revised figures are given in the second part of the table.

Table I shows that between the afternoon and morning ascents, moisture has been removed up to a height of at least 850 mb. This loss of moisture, if deposited on the ground, would give about 1 mm. of precipitation and is much more than any likely deposit of dew. It is therefore necessary to assume that moisture has been diffused upward into the drier upper layers. It is assumed, as seems reasonable, that the effects of advection are unimportant when averaged over 43 occasions. Table I also shows that an initial humidity lapse is followed next morning by an almost uniform water-vapour content to about 3,000 ft.

Table II suggests that the fog point corresponds fairly well to the potential dew point at a level which depends on the lapse rate (referring to the afternoon ascent). The greater the lapse rate the higher the level required.

Although radiation is the cause of the fall of temperature at the surface the mechanism by which the cooling is extended upwards is not clear. Since conduction can be regarded as negligible there remain two possible explanations: (*a*) radiative exchange between the air and the ground, and (*b*) diffusion by turbulence. Exchange of radiation cannot directly affect the distribution of moisture and diffusion by turbulence remains as the only likely explanation of the results obtained.

With an initial lapse of moisture content with height then turbulence obviously leads to a flux of moisture upwards. When the surface temperature reaches the dew point then the lowest levels begin to lose moisture to the ground. Thus there is a tendency towards uniform distribution of moisture throughout a considerable depth of the atmosphere although the total moisture content is reduced by losses to the ground and to the upper drier layers. This is the effect shown by the figures of Table I, although the depth of the layer through which uniform moisture content is reached is, perhaps, unexpectedly large.

With a uniform distribution of moisture it is obvious that any further cooling at the ground leads to an inversion of the normal hydrolapse so that diffusion would then lead to a flux of moisture downwards which would tend to replace the moisture lost to the ground. Such conditions must quickly produce the necessary degree of supersaturation required for fog formation. As diffusion is the factor governing the moisture exchanges it is reasonable to suppose that the upper limit of the effect depends on the initial lapse rate. The more nearly unstable the air initially then the deeper the layer through which uniform distribution of moisture is reached, the less the average moisture content in that layer and the lower the fog point. This is the probable explanation of the results shown in Table II.

In cases where a marked stable layer acts as a " lid " to low-level turbulence then the mixing will be confined to the layers below the " lid ".

The above results have been used for forecasting with some success. They can be stated briefly as follows:—

(*a*) With a lapse rate throughout the lower layers greater than 4°F./1,000 ft. the potential dew point at 850 mb. can be taken as the fog point.

(*b*) If a more stable layer is reached at any lower level than 850 mb. the potential dew point at that level indicates the fog point.

(*c*) If the air is definitely stable from the surface upwards then the surface dew point is itself the fog point.

(*d*) In intermediate cases the fog point is given by the potential dew point at intermediate levels. With a lapse rate of 3–4°F./1,000 ft. the level of 900 mb. would be used.

Exceptions to these rules are:—

Initial inversion of hydrolapse.—For obvious reasons the surface dew point must be the fog point.

Deposit of hoar frost.—When the fog point obtained by the above rules is very near or is below the freezing point then fog formation generally appears to be delayed. This may be due to more moisture being taken from the air in the form of hoar frost than would be taken out as dew, although the magnitude of this hygroscopic effect is very doubtful. Swinbank has suggested that it is negligible. The lower total water-vapour content at these temperatures may itself be the reason for the delay in fog formation.

Wet ground (e.g. rain or showers after or immediately preceding sunset).— In this case evaporation from objects such as trees may continue after the ground has cooled to the dew point and dew deposition has begun. This extra moisture tends to maintain the low-level moisture content whilst the air is stabilizing and so favours fog formation. The fog point obtained by the above rules would then be too low.

The above rules allow for the difference between air over land and air advected from the sea. Whilst the air over land may have a steep lapse rate to several thousands of feet, the air from the sea may have a stable lowest layer or even an inversion. The " sea air " therefore forms fog more readily although its initial dew point may be no higher than that of the air over the land.

The rules given usually have a margin of safety of one or two degrees Fahrenheit before general fog need be expected. There is normally little ambiguity in applying them.

This note is intended only to indicate what appears to be a practicable method of forecasting although as yet no other theoretical support can be given to it.

A CASE OF STRONG TURBULENCE UNDER AN INVERSION

By J. NEUMANN and U. SCHWARZ

Israel Meteorological Service

A case of unusually strong turbulence in the first three thousand feet above the surface near Lydda Airport (Israel) was reported by several pilots on the morning of April 18, 1950. The pilot of a small aircraft returned from a flight after having been nearly overturned in the air.

The case was all the more interesting since the meteorological flight close to the time of the reported turbulence showed the existence of an inversion of 4·6°C. from the screen up to 3,000 ft. The temperature distribution and winds up to 5,000 ft. as measured over Lydda Airport at 0900 L.T. (0700 G.M.T.) are given in Table I.

TABLE I

Height above sea level	Temperature	Wind velocity Direction	Speed
ft.	°C	° true	kt.
5,000	20·8	160	17
4,000	23·6	150	16
3,000	25·4	130	24
2,000	24·3	120	15
1,500	23·7	...	
1,000	23·1	Calm	
500	22·1	...	
Surface	20·8	290	6

The pilot balloon at 0400 showed north-easterly upper winds, and it would appear that between 0400 and 0900, during which period the winds veered to SE. (see Table I), a trough in the low-level easterlies passed the station from the east.* While the surface charts for the 18th indicated the protrusion northward of the Sudan trough (" Red Sea Trough "), the 700-mb. map for 0400 showed a cyclonic shear in a narrow zone between two anticyclones, a minor anticyclone to the west and a major anticyclone to the east.

Temperature and humidity changes at mountain stations, and the great difference in humidities between mountain stations and stations in the coastal area on the 17th demonstrated that a subsidence inversion was in the course of intensification and lowering. Thus, whilst on the 17th relative humidity at Jerusalem (Rephaim station, 2,526 ft.) dropped to 16 per cent. (with a maximum temperature of 29·1°C.), relative humidity in the coastal area was high. Low stratus developed over the latter and persisted near the coast throughout the 18th, the date of reported turbulence.

One of the salient points of the pilot-balloon ascent (see above) is the strong wind shear between 1,000 and 2,000 ft. suggesting that the Richardson number

$$R_i = \frac{g}{T} \frac{\dfrac{\partial T}{\partial z} + \Gamma}{\left(\dfrac{\partial u}{\partial z}\right)^2 + \left(\dfrac{\partial v}{\partial z}\right)^2}$$

computed for that layer and compared with values of R_i considered as critical for the increase of turbulence may throw light on the intensification of turbulence on the morning of the 18th.

It appears from the meteorological flight that the lapse rate between 1,000 and 2,000 ft. was constant and, therefore, in the computation of R_i $\partial T/\partial z$ can be replaced by $\Delta T/\Delta z$, with ΔT=1·2°C. and Δz=1,000 ft.=3×10^4 cm. (approximately). If we now accept that there was a calm at the 1,000-ft. level, we may orientate the x-axis of our co-ordinate system in the direction of 300° and obtain that v=0 at 1,000 and 2,000 ft. Next, assume (*a*) that throughout the layer v=0 and, therefore, $\partial v/\partial z$=0, and (*b*) that it is justified to replace $\partial u/\partial z$ by $\Delta u/\Delta z$; then Δu=15 kt.=772 cm./sec. Thus we obtain

$$(R_i)_{1000-2000}=0{\cdot}70.$$

* As pointed out by Mr. L. Krown.

In the computation the quantity which is most likely to be in error and appreciably affect the value of R_i is Δu. Any error in Δu will magnify the error in the computed value of R_i, in which the square of Δu appears.

Assume that the correct value of Δu is greater than 15 kt. It is very unlikely that it would be so great as to make our R_i smaller than 0·15; in order for R_i to be 0·15 or less, the wind shear would have to be 32·4 kt at least—an improbably large value in the circumstances. It is still less likely that the shear was so great as to make R_i 0·04 or less. It is recalled that values of R_i of 0·04 and 0·15 were considered to be " critical " by various writers.*

If, on the other hand, we assumed that the correct value of Δu is smaller than 15 kt., the resulting R_i would be greater than 0·70, and *a fortiori* greater than 0·15 or 0·04. It is in place here to quote O. G. Sutton: " Thus at present some support can be found from meteorological data for almost any value of Ri_{crit} between 0·04 and 1 . . . "

METEOROLOGICAL OFFICE DISCUSSION

Ice accretion

The first discussion of the 1950–51 series, held at 11 Carlton House Terrace on October 9, 1950, took the form of a review of recent American research into ice-accretion problems. The opening speaker was Mr. G. A. Corby.

The work considered comprised the results of the Harvard–Mount Washington Icing Research Project[1]† obtained during the 1946–47 winter and also the results of flight researches carried out during the 1945–46 and 1946–47 winters by the Ames Aeronautical Laboratory for the American National Advisory Committee for Aeronautics (N.A.C.A.)[2,3].

Mr. Corby explained how the problem of forecasting the occurrence and intensity of aircraft icing had always been hampered by the lack of data available about the quantities most fundamentally involved, namely the liquid water content and the size of the droplets in clouds. This gap in our knowledge accounted for the apparent paradoxes which were common in reports of aircraft icing. Application of a theoretical treatment of droplet trajectories, due to Langmuir and Blodgett[4], had made possible the measurement of the liquid water content and drop size of icing clouds. The technique consisted in the analysis of the rates of accretion obtained on an assembly of cylinders of various sizes after exposure to the icing cloud. The method yielded also an approximate indication of the type of distribution of drop sizes about the mean effective diameter.

An aircraft icing standard had been adopted by the United States Weather Bureau for work of this type, and, on this standard, one unit of icing intensity was defined as accretion at the rate of 1 gm./cm.^{2}/hr. on a 3-in. diameter cylinder moving through the cloud at 200 m.p.h. with its axis perpendicular to the direction of motion. Icing intensities of 1, 6 and 12 on the standard were defined as the boundary values between trace, light, moderate and heavy icing.

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* SUTTON, O. G.; Atmospheric turbulence. London, 1949. p. 89 *et seq.*

† The index numbers refer to the list of references on page 351.

Application of Langmuir's work enabled the icing rate on the aircraft standard to be calculated once the drop size and liquid water content were known and a graphical representation of the relation between the three quantities was used to demonstrate how a particular icing intensity might be caused by a wide variety of combinations of drop size and liquid water content, and how apparent paradoxes arose in the past because of the lack of knowledge of these quantities.

A comprehensive series of measurements of liquid water content, drop size (mean effective diameter) and the derived variable, icing rate on the aircraft standard, had been made from the summit of Mount Washington, New Hampshire, U.S.A., which is enshrouded in cloud at temperatures below freezing for much of the winter. The mean values obtained for liquid water content, mean effective drop diameter and icing rate were 0·472 gm./m.^{3}, 13 microns and 4·09 gm./cm.^{2}/hr. with standard deviations of 0·269, 5·1 and 3·66 respectively. A statistical analysis had revealed real positive correlations between the icing rate and both the liquid water content and the drop size, but Mr. Corby felt that these correlations had little practical meaning since the icing rate was analytically related to the other two quantities.

The broad relations found between the icing rate and the synoptic situation were mostly peculiar to North American winter conditions, and in any event would be of little value for forecasting owing to the wide variations of icing rate within each situation. Although no connexion had been found between the icing variables and the lapse rate, Mr. Corby considered that such effects had probably been masked by the changes in the physical state of the clouds caused by the forced ascent at the mountain.

An investigation of errors in the rotating cylinder measurements caused by loss of some of the intercepted water before freezing ("run-off") and loss of fragile rime due to the action of the wind ("blow-off") had shown that neither cause had significantly affected the Mount Washington results but that "run-off" errors might be large at aircraft speeds.

It had not been possible to confirm or deny from the icing observations at low temperatures the existence of the $-41°$C. limit identified by Cwilong[5,6] and others as being the critical temperature for the effectiveness of sublimation nuclei in the atmosphere, and no temperature limit could therefore be set below which aircraft icing would be impossible.

Substantial reductions in the liquid water content of clouds had been brought about on some occasions by the introduction of dry ice into clouds covering the summit. A method was demonstrated of estimating from a representative tephigram ascent the maximum possible liquid water content of clouds formed by local convection and low-level turbulence.

The flight researches carried out for the American National Advisory Committee for Aeronautics comprised 557 measurements of the drop size and liquid water content of icing clouds by means of the rotating cylinder method. The ranges of values of these quantities were, generally speaking, consistent with the Mount Washington data.

The idea of forecasting icing intensity on the aircraft standard by using a value of the liquid water content, estimated from radio-sonde data, in association with a mean value of the drop diameter for the cloud type (14 microns for layer clouds and 17 microns for cumulus clouds) had been examined with

promising results. In addition, a set of tentative qualitative forecasting rules had been evolved.

In considering the problem of defining the worst icing condition likely to be encountered in a given area, for use by the designers of de-icing systems, two distinct aspects had been recognized: the probable maximum icing condition irrespective of its extent or duration and the maximum continuous icing condition with which de-icing equipment might be expected to deal indefinitely. Values for these two conditions applicable to the United States were quoted. The problem had also been dealt with from a statistical viewpoint and the results specified in the form of the worst icing condition likely to be encountered once in a given number of icing flights over given flight path distances.

The Director, opening the general discussion, drew attention to the difficulties of measuring drop-size distribution, and asked how this quantity had been measured by the U.S. workers. He was surprised that, in view of the work of Cwilong and others on sublimation nuclei, the American work revealed no clear connexion between icing and altitude at great heights. As the duration of an icing instance decreased with the intensity, he wondered whether it was possible to identify a maximum " dosage " of ice deposit.

Mr. Corby explained briefly how the size distribution of the droplets was approximately determined in terms of a set of defined distributions having various degrees of departure from uniformity. It was possible to fly in icing layer cloud more or less indefinitely and this would rule out the possibility of establishing a maximum icing " dosage".

Mr. G. F. W. Oddie quoted a case of icing encountered by the " Comet " jet airliner at a temperature of −60°C.

Mr. Best queried whether it was possible to fly in a supercooled liquid cloud without ice forming. He was doubtful whether the relation between temperature and icing found at Mount Washington would apply to aircraft icing owing to the mountain results being obtained at a fixed altitude. He regretted that the descriptive terms for icing intensity were related to accretion on a fixed-size cylinder.

Mr. Corby felt that reports of no icing in supercooled cloud might well be cases of intensities too small for visual observation.

Mr. Bradbury pointed out that in most pilots' reports icing appeared to be associated with turbulence.

Mr. Corby thought this was because turbulence was common in convective clouds which also gave rise to most significant icing cases.

Mr. D. D. Clark said that icing must vary considerably with the type and speed of the aircraft, and wondered, therefore, how the results were affected by the aircraft and also by the de-icing system in use.

Mr. Corby explained that the type of aircraft and its de-icing equipment did not affect the results, which were obtained from the rotating cylinder measurements and not from the accretion on the aircraft itself.

Dr. Frith quoted from his own experience to substantiate the contention that rotating cylinders pick up snow crystals as well as supercooled water droplets. The amount of ice was not the only important factor since variations in the shape of the deposit affected the aircraft performance in various ways. He

thought that the apparent lack of icing in some supercooled clouds might be due to the kinetic heating effect.

Mr. Gloyne explained how Langmuir's theoretical work on droplet trajectories and the rotating cylinder technique were being applied to meteorological research into agricultural problems, e.g. insecticide spraying, etc.

Dr. Palmer (Clarendon Laboratory) showed how the reports of icing at very low temperatures were not necessarily inconsistent with the results of Cwilong's work on sublimation nuclei. An insufficiency in the free atmosphere of the nuclei operative at $-41°C.$ would account for the existence of liquid clouds at temperatures below that limit.

Mr. Wallington drew attention to the fact that aircraft in congested areas might be forced by Air Traffic Control procedures to fly for long periods in icing conditions. He quoted an instance of two Viking aircraft encountering very different icing conditions in the same cloud layer at almost the same time. In reply to a query, he was told that there was as yet no method of predicting the maximum liquid water content of clouds other than cumulus and strato-cumulus.

Mr. B. C. V. Oddie thought that caution would be necessary in applying the results to forecasting in the United Kingdom since they were determined for American winter conditions.

Mr. Corby, replying to a question by Mr. Sawyer, said that errors due to run-off losses must have been considerable in some of the aircraft measurements but no particular investigation of this was mentioned in the N.A.C.A. report.

Dr. Sutcliffe asked whether current Meteorological Office publications were affected by this new work, especially as regards the forecasting of the icing index.

Mr. Corby said that some modification in the guidance given for forecasting icing index would be necessary in the light of the American work.

Mr. Absalom mentioned that this had been allowed for in a new *Meteorological Report* on icing to be issued by the Meteorological Office in the near future.

Points raised by other speakers concerned the connexion between icing and the appearance of clouds, the occurrence of rain ice and the limitations of the rotating cylinder technique as a method of measuring the icing variables.

The Director, in closing the discussion, welcomed the advances which had been made in the complex subject of aircraft icing and commented on the great practical difficulties of the experimental work involved.

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METEOROLOGICAL RESEARCH COMMITTEE

The 13th meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on October 26, 1950. A paper by Dr. Pasquill[1], in which the aerodynamic and water-tank methods of estimating natural evaporation were compared, was discussed. Despite the fundamental differences in approach by the two methods, Dr. Penman contended that both methods give substantially correct answers and supported his contention with a number of numerical examples.

Dr. Frith summarized the results of an investigation of inhomegeneities in the upper air on the 50-Km. scale[2], and it was agreed that an attempt should now be made to relate such inhomegeneities to the synoptic situation.

Another aspect of upper air research—the relation of frost point observations to aircraft condensation trails[3]—was also considered.

[1] *Met. Res. Pap., London,* No. 579, 1950
[2] *Met. Res. Pap., London,* No. 583, 1950.
[3] *Met. Res. Pap., London,* No. 576, 1950

ROYAL METEOROLOGICAL SOCIETY

The meeting of the Society held on October 19, 1950, with Dr. R. C. Sutcliffe, Vice-President, in the Chair, was a discussion meeting on the use of films in meteorology arranged by the Society and the Scientific Film Association.

Professor Sir David Brunt, F.R.S., spoke of the great value of films in research work in enabling, in effect, an experiment to be studied many times, and of the light on slow meteorological processes such as cloud formation obtained by showing the film at some 30 times the rate of photographing.

Mr. Jenkins of the Ministry of Education, dealing with the use of films in school teaching, pointed to their value in bringing the subject to life. He considered that, for class-room use, only one idea was needed in a film and that 10 min. was long enough.

Dr. J. S. Farquharson, speaking as one who had been meteorological adviser in the making of some Air Ministry meteorological films for aircrew instruction, pointed out some of the points which needed to be considered in making: such as absolute synchronism of sight and sound, and the necessity for a clear understanding of the purpose of the film and the audience to which it was to be shown before the script was written. He mentioned the high cost of film-making.

Mr. P. J. Meade considered that scientific films could not replace the teacher in the instruction of meteorological staff. He referred to the rapidity with which they went out of date and the difficulty of revision.

Mr. J. D. Chambers of the Scientific Film Association gave some interesting facts on the cost of film-making and the necessity for shooting much more than was actually needed for the final film and drastically editing it.

The documentary film " Spotlight on Weather " made by 20th Century Films at Dunstable and on an ocean weather ship, and the research film " Seeding the Clouds " by Dr. V. J. Schaefer, U.S.A., were then shown. " Spotlight on Weather " gives scenes of work at the Central Forecasting

Office and on an ocean weather ship; and " Seeding the Clouds " gives vivid pictures of cumulus-cloud development and the effect of cloud seeding, either artificially or naturally, by the fall of ice crystals from above.

ROYAL ASTRONOMICAL SOCIETY

Variations in the length of the day

A geophysical discussion on " Variations in the length of the day " was held by the Royal Astronomical Society on November 24, 1950, under the chairmanship of Mr. E. Gold. The regularity in the rotation of the earth provided man with his first master clock; it is only in recent years that standards of time measurement have been improved sufficiently to show, by direct comparison, any variability whatever although slow secular changes have earlier been inferred from astronomical records. The Astronomer Royal, in a brief review of the way knowledge on this subject has been gained, referred to three irregularities. The slow secular lengthening of the day by some 0·001 sec./100 yr. had been satisfactorily explained, as the result of tidal friction, by Taylor and Jeffreys. A long-period fluctuation, related with Newcombe's " great empirical term " in the motion of the moon, still awaits an explanation, and now there is convincing evidence, provided mainly by quartz-crystal clocks, of an annual variation. The earth rotates more quickly in August than in February, giving a total range of about 0·002 sec. in the day's length—over two parts in 10^8.

Dr. R. C. Sutcliffe discussed the possible meteorological causes of this annual variation on the principle of the conservation of angular momentum for the combined system of earth and atmosphere. The atmosphere contributes to the total angular momentum about one part in 6×10^5 so that a variation of 2 parts in 10^8 in the earth would require an opposite variation of about 1·2 per cent. in the atmosphere's contribution. Such a variation in the angular momentum of the atmosphere could be achieved either by redistributing the mass of atmosphere (effectively altering the surface pressure) or by varying the relative motion of earth and atmosphere (effectively altering the zonal component of wind). Dr. Sutcliffe's calculations showed that the effect of surface-pressure changes gave only about 1 per cent. of the required amount, but the effect of varying wind is of the right sense and magnitude and was estimated at about one quarter of the required effect. This estimate was based on upper winds derived from the recently published *Geophysical Memoir*, " Upper Winds over the World"*. This is undoubtedly the best available work on the subject although it already requires revision in the light of new data particularly from those high levels where the maxima of momentum are found in association with the jet stream.

Dr. J. N. Carruthers followed with a discussion of the possible oceanographic effects. He and his colleagues had collected all available data on the change in mean sea level between spring and autumn. There was apparently more water between 45°N. and 45°S. in the northern spring, represented by an average rise of mean sea level by a few centimetres, and this could account for some 10 per cent. of the required effect. Data so far analysed did not permit the study of the annual curve of variation in mean sea level, and if it were found to be sinusoidal and phased in closely to the known curve of variation in the length

* BROOKS, C. E. P., DURST, C. S., CARRUTHERS, N., DEWAR, D. and SAWYER, J. S.; Upper Winds over the World. *Geophys. Mem., London*, **10**, 1950, No. 85.

of the day the total effect might be comparable with the whole effect required. Reference was made to a discussion of the whole subject by Munk and Miller[*] who concluded, as did Dr. Sutcliffe, that wind variations were the important factor and, further, that oceanographic effect would not account for more than 15 per cent. of the required amount. Munk and Miller found that the entire effect could be obtained from the wind but used only vertical cross-sections through 80°W. and 100°E. as the basis of computation. There is a good deal of synoptic evidence to suggest that these longitudes are not representative of the zonal flow over the earth as a whole and are indeed regions of abnormally large variability of momentum in the northern hemisphere. It may safely be concluded that wind variations provide an important contribution, but until the meteorologists have provided a firmer estimate it would be unwise to dismiss the oceans altogether.

R. C. SUTCLIFFE

LETTERS TO THE EDITOR

Tropical rainfall from cloud which did not extend to the freezing level

In the August 1950 issue of the *Meteorological Magazine* some notes were given on rainfall in the tropics from cloud not extending above the freezing level. Such rain is by no means an infrequent occurrence in east Africa but opportunities of making precise measurements of cloud tops and temperature are rare. The following account of a flight from Nairobi to Mombasa on October 5, 1950, is therefore of particular interest.

The aircraft took off from Mombasa at 0750 G.M.T. on a course of 316°. Over the hills, 20–30 miles inland, the captain of the aircraft noticed rain falling from cumulus clouds some five miles to the south of the track. The cloud base was a few hundred feet above the ground and the tops were 10,500–11,000 ft. above M.S.L. There was no evidence whatsoever of anvil formation and the sky was clear above. The captain of the aircraft took the following psychrometer readings, which are uncorrected for an indicated airspeed of 95 kt.:–

Time	Altitude		Temperature dry bulb	Temperature wet bulb	Remarks
G.M.T.	ft.	mb.	°F.	°F.	
0755	1,000	—	75	72	
	2,500	—	68	68	cloud base
	3,000	904	66	66	
	4,000	873	63	62	
	5,000	841	60	58	
	6,000	811	55	55	extremely turbulent
	8,000	—	48	48	
0813	9,000	729	45	45	
	9,500	714·5	43	43	
	10,000	701	43	41·5	
0819	10,500	—	40	39	cloud heads
0828	10,400	691·5	40	38	
0846	10,500	—	40	38	
0900	10,500	689	40	38	

D. A. DAVIES

East African Meteorological Department, Nairobi, Kenya, October 30, 1950

[*] MUNK, W. H. and MILLER, R. L.; Variation in the earth's angular velocity resulting from fluctuations in atmospheric and oceanic circulation. *Tellus, Stockholm*, **2**, 1950, p. 93.

Simultaneous aircraft soundings of temperature and frost point

For several years now the Meteorological Research Flight has made frequent aircraft soundings to heights of about 40,000 ft. to measure the temperature and humidity of the upper air and to make other observations. Recently it has been our practice to make an occasional sounding employing two aircraft in formation, observations being made independently, but as far as possible simultaneously, in each. This provides a check of the instruments and their reliability.

It is thought that readers of the *Meteorological Magazine* may be interested to see the results of two of these " double ascents". Fig. 1 shows the results of a sounding made on the afternoon of August 14, 1950, and Fig. 2 one on the morning of October 5, 1950, both over Farnborough. The comparatively large differences in both temperature and frost point at the three highest levels in Fig. 1 may be explained by the fact that the aircraft were 10–20 miles apart. During all the other observations on both dates the aircraft were close together.

The good agreement of the temperature measurements, which were made using Meteorological Office flat-plate electrical resistance thermometers, was

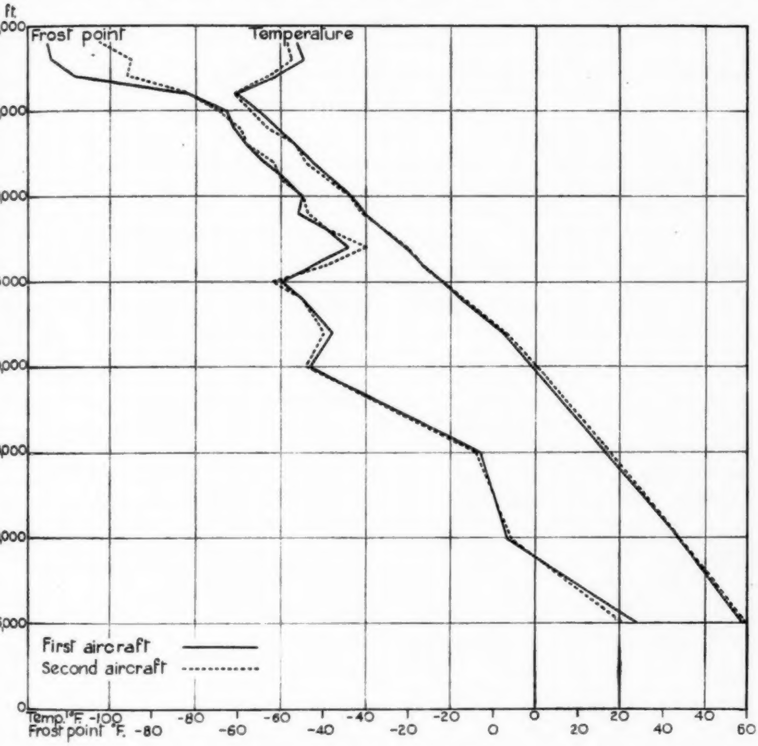

FIG. 1—SOUNDING BY TWO AIRCRAFT IN FORMATION OVER FARNBOROUGH 1410–1540 G.M.T., AUGUST 14, 1950

For clarity the frost-point readings are all displaced 10°F.

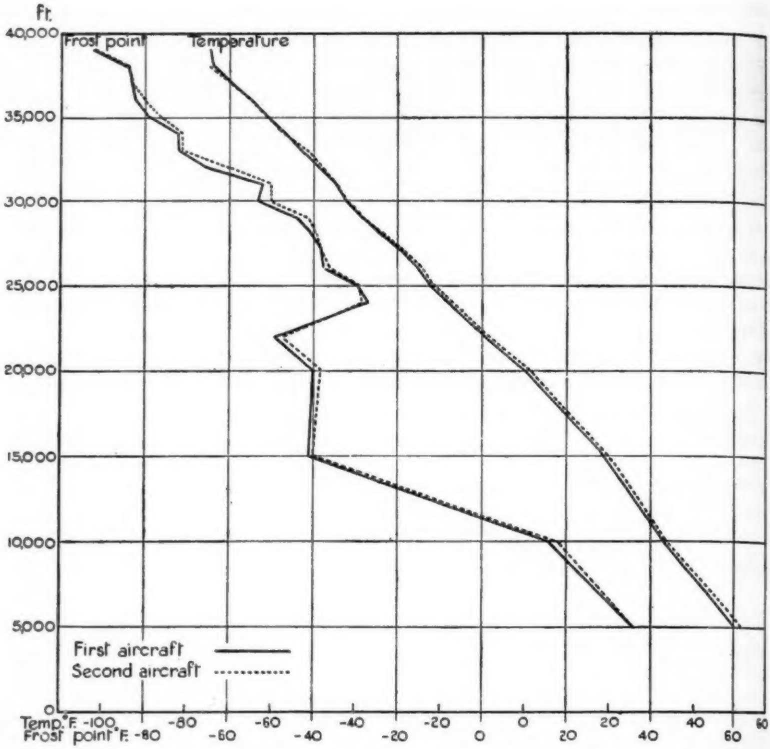

FIG. 2—SOUNDING BY TWO AIRCRAFT IN FORMATION OVER FARNBOROUGH 1015–1130 G.M.T. OCTOBER 5, 1950

For clarity the frost-point readings are all displaced 10°F.

to be expected. That of the frost-point measurements, made by means of the Meteorological Office Mk IIa pressurized aircraft frost-point hygrometer, is more remarkable. This instrument requires considerable practice to operate, particularly at low frost points, but these observations indicate that measurements made by experienced observers are satisfactorily reliable and repeatable.

H. E. SHELLARD

Farnborough, Hampshire, November 9, 1950

NOTES AND NEWS

Orkney windmill

Opposite is an artist's impression of the first large-scale windmill in Great Britain for the generation of electricity for public supply. It is being made by John Brown & Co. Ltd., for the North of Scotland Hydro-Electric Board and will be erected on Costa Hill, Orkney.

In northern and western Scotland, a considerable volume of power could be produced from the winds if economical and reliable machines were available

[*To face p. 356*

ARTIST'S IMPRESSION OF WINDMILL FOR ELECTRICITY GENERATION ON COSTA HILL, ORKNEY

To face p. 357]

TROPHIES AT PRESENT HELD BY THE METEOROLOGICAL OFFICE

Left to right.—**Londonderry Cup** for golf; **Halahan Challenge Shield** for the tug of war championship; **Air Ministry Football Challenge Cup**; **Bishop Shield** awarded to the Division which has the best record for the year in Sports activities; **Air Ministry Cricket Challenge Cup**; **Bristol Challenge Cup** awarded to the Operating Company or Airport Department scoring highest aggregate points at the London Airport Annual International Sports (won by the Meteorological Office, London Airport); **W. S. Jones Memorial Cup** awarded to the Division scoring the highest number of points at the Annual Sports Meeting.

and this experimental windmill has been designed as a first step towards solving the mechanical and aerodynamic problems involved.

The tower will be built of steel and its foundations on solid rock. Each sail will be 30 ft. long. The nacelle, 78 ft. above ground, will contain a gear box and generator and will rotate to keep the rounded end facing the wind.

The rated output of the windmill is 100 Kw. and it will be connected to the Hydro-Electric Board's network on the mainland of Orkney.

Guidance on the meteorological factors concerned has been provided by the British Climatology Branch of the Meteorological Office.

The movement of jet streams and the wind hodograph

A common feature of synoptic charts for levels in the upper troposphere is a jet stream. In it winds of high speed extend for several hundred miles along the track of the wind, but to either side and above and below there is a sharp decrease in velocity. If the air forming a jet stream in the upper troposphere remains at the same distance from the axis of the jet during its passage through the region, then the movement of the jet perpendicular to its axis would be the same as the wind component in that direction. An examination of several jet streams in this respect was made by Mr. T. Shaw in the course of upper air studies in the Forecasting Research Division. The results are briefly described below, because although they do not promise any reliable method of forecasting the movements of jet streams, nevertheless they may be of interest to those confronted with this problem.

The data examined related to six periods during 1949 when jet streams were over the British Isles. The position of the jet stream was estimated on contour charts of the 300-mb. surface drawn at 6-hr. intervals, and hodographs were plotted in respect of the wind soundings from stations near to the axis of the jet. Fig. 1 represents an idealized wind hodograph for a station beneath

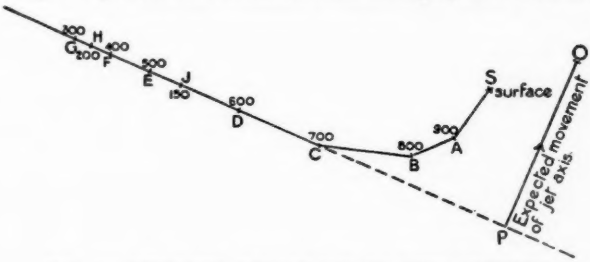

FIG. 1—IDEALIZED HODOGRAPH OF WIND SOUNDING THROUGH JET STREAM

Figures indicate pressures (in mb.) of levels of wind observations.

a jet stream. With respect to the origin at O, the point S represents the direction and velocity of the wind at the surface, i.e. the wind direction is from S to O and the wind velocity is proportional to the length of SO. Similarly the points A, B, C, etc., represent the winds at successive pressure levels at 100-mb. intervals (50-mb. intervals were used in the investigation). The straight section GC defines the thermal wind direction in the jet and is aligned approximately parallel to the axis of the jet. The perpendicular OP from the origin

approximates to the wind component perpendicular to the jet axis. Wind hodographs near the jet streams were examined, a straight line GP was drawn passing as nearly as possible through the representative wind points in and below the jet, and PO was measured.

The direction of movement of the axis of the jet, as suggested by the hodograph, was in good agreement with the observed motion—only one hodograph out of the 53 studied gave an indication in the wrong sense. There was only moderate agreement between the predicted speed of movement and the actual speed of the axis of the jet over 6-hr. intervals—errors were less than 15 kt. in most cases, compared with the average speed of the jet of 20–25 kt. The hodograph component, PO, varied considerably from sounding to sounding within the same jet stream. However, for two of the jets, the mean value of the component PO was calculated for a sequence of several soundings in the same jet stream and good agreement was achieved with the speed of the jet axis as obtained from its displacement over the longer period. In these two cases calculated displacements were 486 miles in 18 hr. (April 4–5, 1949) and 390 miles in 24 hr. (December 5–6, 1949) compared with observed displacements of 450 miles and 410 miles respectively.

There were difficulties in determining the axis of the jet streams; wind observations were rarely made centrally with respect to the jet; also there was occasionally some uncertainty in estimating the value of the hodograph component PO when the features of the wind hodograph were indefinite. The findings of the investigation are, therefore, not conclusive, but there is enough evidence to suggest that the movement of a jet stream perpendicular to its axis is closely related to the component in this direction of the wind within the jet.

J. S. SAWYER

International exchange of views on the operation of ocean weather ships

On September 4, 1950, the U.S. Coast Guard Cutter *Castle Rock* arrived in Glasgow after a spell of duty at ocean weather station ABLE (62°N., 33°W.). Cdr. Graves, Captain of *Castle Rock*, was for many years engaged on ice-patrol duties, was a meteorological adviser to the coast guard authorities at Washington, attended the first weather ship conference in London, and was at the I.M.O. Conferences at Toronto and Washington in 1947. Mr. Hill, of the U.S. Weather Bureau, Meteorological Officer aboard *Castle Rock*, is a veteran sea-going meteorologist, having served in ocean weather ships since their inception.

On September 7, Cdr. Graves and three of his officers, accompanied by Cdr. Frankcom, visited *Weather Observer*, which was at anchor at the Tail of the Bank. They inspected the ship thoroughly, exchanged views with the officers and were entertained to lunch aboard. Later they saw a radio-sonde ascent and an air sea rescue exercise carried out with a force 7 wind. After leaving *Weather Observer* they visited Prestwick airport.

On the following day, Cdr. Frankcom, the shore captain and the Master of *Weather Recorder*, paid a return visit to Cdr. Graves and thoroughly inspected *Castle Rock*. This opportunity of making a personal exchange of views upon the operation of these ships can be nothing but beneficial.

International operation of an ocean weather station

August 23, 1950, in the delightful setting of Bergen harbour, saw the ending of one very pleasant international fellowship, and the inauguration of another which it is hoped will be equally fruitful. The ocean weather station MIKE, off the coast of Norway, is manned by the former " Flower " class corvettes *Polarfront I* and *Polarfront II*, which were converted for the purpose in British Admiralty Dockyards and have been operated jointly by Norway, Sweden and the United Kingdom. In future, as a result of the second ocean weather ship conference, the British responsibility for the operation of this station will be taken over by Denmark and Belgium.

To commemorate this change-over of international responsibility, representatives of the countries concerned assembled aboard the O.W.S. *Polarfront I*. It was interesting to note that two of the Stewards aboard this small ship are women, and their presence aboard was shown in the homely atmosphere of the wardroom.

After the ship's return to Bergen, a dinner was held for the various delegates at which speakers stressed the very amicable relations which had been maintained between the Scandinavians and the British authorities throughout the Anglo-Scandinavian operation of station MIKE.

Geochimica et Cosmochimica Acta

We have received from the publishers, Messrs. Butterworth-Springer Ltd., Bell Yard, London, W.C.2, a copy of the first number of a new journal which bears the title quoted above and which is to publish research papers on geochemistry and cosmic chemistry.

The first number contains articles on the structure of recently fallen meteorites and on the chemical constitution of certain minerals, oceanic waters and sediments.

The British editors are Professor Paneth, F.R.S., Professor Wager, F.R.S., and Dr. S. R. Nockalds. The other editors represent the U.S.A., Sweden and Germany. The journal is to be published in parts at irregular intervals, composing volumes of about 300 pages, priced at £3 10*s*. 0*d*.

REVIEWS

The Flight of Thunderbolts. By B. F. J. Schonland. Size: $8\frac{3}{4}$ in. $\times 5\frac{1}{2}$ in., pp. viii+152. *Illus*. Geoffrey Cumberlege, Oxford University Press, 1950. Price: 15*s*. 0*d*.

When a distinguished scientist takes the title of a book on the subject of his life's work from a line in the " Mikado " an unusual result may be expected. Dr. Schonland has contributed as much to modern knowledge of lightning phenomena as any other man since Franklin. The results of his investigations were reported to the Royal Society in a long series of papers. Apart from the clue provided by the title, those acquainted with his work might have expected to receive from his hands a co-ordinating account of the results obtained by himself, his collaborators and other workers on the same and related subjects.

The author has decided otherwise. He addresses the general reader and he does so by omitting all mathematics, specialized terminology and detailed numerical information. Instead, he presents his " case history", as he calls it,

in every-day language, and he does it so skilfully that it makes the reading even of complex physical explanations a matter of pure pleasure. He makes fun of popular fallacies, debunks widely held beliefs, and enlivens his explanations by highly characteristic and often amusing hand sketches. In short, he easily succeeds in holding the attention of the reader throughout an account which extends from the folk-lore of primitive people to an original theory of the sudden cloud-burst connected with the first lightning stroke of a heavy thunderstorm.

An historical review of ancient beliefs and myths, with particular reference to South African tribes, is followed by a description of striking examples of lightning damage to buildings and ships and the detailed story of Franklin's experiments culminating in the invention of the lightning conductor and its early application in Europe and America. In describing the various types of lightning flashes the author expresses a certain scepticism for popular accounts of ball lightning. He deals with the effect of lightning on buildings and trees, the colour of lightning, the frequency of thunderstorms and the sound of thunder.

The historical development of the Boys camera, which in Dr. Schonland's hands became the key to our modern knowledge of the lightning discharge, is described, and there follows a detailed analysis of the mechanism of the lightning discharge in its various stages. Some recent observations of the cell structure of thunderclouds gives the author a novel clue to the mechanism of multiple lightning-stroke flashes.

A further chapter is devoted to the protective effect of a lightning conductor and its range of protection, a subject which has remained of widely controversial nature up to the present time, and on which Franklin's views appear to have been nearer the truth than those of many of his followers. Basic rules are given for the protection of buildings, human beings and livestock.

To the physically minded meteorologist it should be a challenge that, with all our present-day knowledge of the lightning discharge itself, the actual mechanism underlying the electrification of thunderclouds remains still unsolved. The author explains the various existing theories and shows their practical application in artificial rain-making.

The distant electrical effects of lightning discharges are examined with particular reference to the atmospherics which constitute the bane of radio reception, and which, from the author's investigations, led to new knowledge on the height of the reflecting ionospheric layer. The importance of this new knowledge for wireless communication and thunderstorm forecasting is underlined.

In the case of a book which gives the reader throughout as much pleasure as it clearly gave the author to write it, the reviewer hesitates to draw attention to slight shortcomings. Suffice it therefore to say that the author occasionally refers to the most frequent value of a parameter where the mean value is intended (e.g. charge in a lightning flash and amplitude of lightning current) and that he states that 10 per cent. of all strokes produce current amplitudes of less than 20,000 amp., whereas it is at least 50 per cent.

The book is excellently produced, and will, it is confidently expected, greatly increase the existing small circle of people who share the author's "passion for a flight of thunderbolts".

R. H. GOLDE

Australian drought cycles. By V. R. Aldis. *The Australian Surveyors*, June–Sept. 1949. pp. 16. Institution of Surveyors, Sydney, N.S.W.

The well defined trends in the Australian rainfall pattern are brought out by curves of the 3-year running means at stations with long records. It is shown that the periods of rain deficiency are spaced at intervals of about 15 years and, following the recently ended period of marked rainfall deficiency, the present prospect is stated to be a relatively increased rainfall during the next decade. At the same time it is admitted that " true mathematical periodicity undoubtedly does not exist " !

J. GLASSPOOLE

BOOKS RECEIVED

The general characteristics of squalls at Peshawar. By C. Ramaswamy and K. C. Majumdar. *Mem. India met. Dep., Delhi*, Vol. XXVIII, Pt. I. Size: $11\frac{3}{4}$ in. × $9\frac{1}{4}$ in., pp. 1–53, *Illus.* Manager of Publications, Delhi, 1950. Price: *Rs.* 7–8 or 11*s.* 6*d.*

Rainfall at Peshawar. By C. Ramaswamy and N. Suryanarayana. *Mem. India met. Dep., Delhi*, Vol. XXVIII, Pt. III. Size: $11\frac{3}{4}$ in. × $9\frac{1}{4}$ in., pp. 121–37, *Illus.* Manager of Publications, Delhi, 1950. Price: *Rs.* 3–6 or 5*s.* 6*d.*

Discussion on a method of predicting night minimum temperature in winter. By K. C. Chakravortty. *Sci. Notes India Met. Dep., Delhi*, Vol. XI, No. 135. Size: 10 in. × 7 in., pp. 39–46. Manager of Publications, Delhi, 1950. Price: *Rs.* 1–2 or 1*s.* 9d.

Annual Reports 1940, 1942, 1946 and 1947. Apia Observatory. Size: $9\frac{1}{2}$ in. × 6 in. pp. iv + 167, iv + 166, ii + 146 and ii + 158. New Zealand Department of Scientific and Industrial Research, Wellington. Prices: 5*s.*, 5*s.*, 6*s.* and 6*s.*

Die Bestimmung de Komponenten der atmosphärischen Trübung aus Aktinometermessungen. By Walter Schüepp. *Archiv. Met. Geophys. Bioklimat.* B, **1**, 1949, pp. 259–346. Size: 9 in. × 6 in., *Illus.* Springer-Verlag, Vienna.

METEOROLOGICAL OFFICE NEWS

Forecasts for farmers.—During the harvest month of September, many inquiries from farmers were received by the forecasting offices listed in the Post Office Guide. Over 100 inquiries were dealt with at each of the following offices: Shawbury, Southampton, Gloucester, Upavon, Abingdon, Bawtry, Mildenhall and Mount Batten. The greatest demand was at Abingdon where 420 requests were received.

Letters received from County Secretaries of the National Farmers' Union have shown how much this service has been appreciated.

Ocean weather ships.—Service in ocean weather ships is voluntary and up to the present it has been possible to fill all the posts; indeed, the number of Assistants who have volunteered has been more than was needed. However, additional officer volunteers are now required—Assistant Experimental Officers in particular. All who are interested are invited to send their names to the Director (M.O.10).

Living accommodation at R.A.F. stations.—Staff will be glad to learn that a house is to be provided for a meteorologist at some 40 permanent Royal Air Force stations in this country at which 24-hour rosters are not worked but staff are liable to be called upon for duty outside normal hours.

R.A.F.V.R. Meteorological Section.—A programme of continuous training for the year 1950 carried on well into October. About 25 per cent of the total strength of the section took their continuous training during the period of the R.A.F. Autumn Air Defence exercise.

During the recruiting drive at the September meeting of the R.A.F. Meteorological Association, it came to light that many potential recruits had refrained from volunteering for the Meteorological Section of the R.A.F.V.R. in the belief that training would make greater demands upon them than they would be able to meet. The prevailing impression seemed to be that "non-continuous" training (week-ends and evenings) would take the form of a series of short lectures necessitating many attendances over the year. In fact, non-continuous training is performed mainly at the forecaster's desk where comparatively few periods of practical work make up the prescribed 90 hours non-continuous training per annum.

Obituary.—Staff who have served at Kew Observatory will learn with regret of the death on November 11, 1950, of Mr. Bertram Francis at the age of 70. He was a member of the staff of the Observatory when it was taken over by the Meteorological Office in 1910, and remained there until his retirement in 1945.

Sports activities.—Facing p. 357 is a photograph of the trophies at present held by the Meteorological Office. In addition to these, six individual challenge cups are held by members of the staff.

Contributions to *Meteorological Office News*, which should be brief, will be welcomed. New uses for meteorological information, unusual personal experiences, and activities or achievements of staff are subjects of interest to readers.

WEATHER OF OCTOBER 1950

Mean pressure was between 1020 and 1022 mb. around the Azores, over the Bay of Biscay, central France and central Europe, and between 1015 and 1019 mb. over the eastern half of the United States and in Quebec. It was below 1000 mb. south-westward of Iceland, and below 1005 mb. in western Alaska and the Aleutian Islands.

Over nearly the whole of Europe, and most of the Mediterranean, it was slightly above the average for October. The excess amounting to 5 mb. over part of northern France. South-westward of Iceland, however, there was a deficit of more than 5 mb. Over most of North America mean pressure was slightly below the average, the deficit exceeding 5 mb. in Idaho, the west of Montana and states further west, and in British Columbia.

In the British Isles, the month was dry in the east and south but rainfall exceeded the average on the whole in the north-west.

The tracks of the main depressions were almost all to the north of the British Isles. In the opening days a depression moved north-east across north Scotland causing rain or showers generally, with somewhat widespread thunderstorms in England and Wales. On the following days a very deep Atlantic depression moved north-north-east to the south of Iceland and an associated trough crossed the British Isles; heavy rain fell in the north-west on the 3rd but little or none occurred in eastern and midland districts of England (3·76 in. at Glenquoich and 2·81 in. at Kinlochourin, both in Inverness-shire). The 5th

in particular, was a warm, sunny day in most areas, temperatures reaching 70°F. at a large number of places in England and touching 75°F. in London, at Camden Square. On the 6th and 7th another Atlantic depression approached the Faeroes and then turned north-north-east, while a trough crossed the British Isles causing showers in western districts; on the 8th a cold front, moving east, was associated with widespread thunderstorms in the northern half of the country. Thereafter a depression north-west of Scotland moved a little north-east and then turned east along our northern seaboard; rain fell generally on the 9th mainly slight in the east of Great Britain but heavy, with local thunderstorms, in the north-west (2·13 in. at Glencoe, Argyll). Subsequently a ridge of high pressure moved east over the British Isles and combined with an anticyclone over northern Scandinavia; a mainly fair day, with good records of bright sunshine was experienced in Great Britain on the 11th but more rain occurred later in Scotland and Northern Ireland. A deep Atlantic depression moved north-east to Thorshavn from the 12th to the 14th causing further rain, chiefly in the north and west, though slight rain occurred in eastern England also on the 13th. On the 16th a trough of low pressure off our western seaboard moved east and heavy rain was registered in the north-west (1·75 in. at Glenbranter, Argyll, and 1·38 in. at Ambleside). Local gales occurred rather frequently at exposed places in the north-west and north during the first 17 days.

Subsequently the Azores anticyclone moved north-east and later a ridge of high pressure moved in over Scotland from the west. Anticyclonic conditions prevailed for the most part from the 18th to the 20th, with appreciable fog, particularly in England and Wales, on the 19th and 20th. On the 21st and 22nd the anticyclone moved east to southern Scandinavia and Denmark, while a trough of low pressure moved in over our western districts giving further rain there. Subsequently another anticyclone off the west of Ireland moved north-east to southern Scandinavia and a dry spell set in, which lasted until the 25th. In the rear of the anticyclone a slow-moving, shallow trough, associated with a depression off south-west Iceland, moved over the British Isles and caused rain or showers in many places. On the 29th a depression over Holland, moving irregularly south-east, was associated with showers in eastern England. In the closing days of the month troughs of low pressure moved east over the British Isles. Rain, rather heavy in places, fell on the 30th and scattered rain or showers, chiefly in the west, on the 31st. The last week was cold and unusually low minimum temperatures for the season occurred, particularly from the 27th to the 29th (20°F. at Porton on the 28th and 18°F. at Dalwhinnie on the 29th); fog was also widespread at times.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	75	21	0·0	44	−6	100
Scotland	66	18	+0·2	98	0	98
Northern Ireland ...	64	27	+0·3	108	+2	98

RAINFALL OF OCTOBER 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	·41	16	*Glam.*	Cardiff, Penylan ...	1·78	37
Kent	Folkestone, Cherry Gdn.	1·01	25	*Pemb.*	St. Ann's Head ...	...	...
,,	Edenbridge, Falconhurst	·18	5	*Card.*	Aberystwyth	3·45	[illegible]
Sussex	Compton, Compton Ho.	·84	18	*Radnor*	Tyrmynydd	3·54	54
,,	Worthing, Beach Ho. Pk.	·69	19	*Mont.*	Lake Vyrnwy	5·01	86
Hants.	Ventnor, Roy. Nat. Hos.	1·07	27	*Mer.*	Blaenau Festiniog ...	11·66	114
,,	Bournemouth	·83	19	*Carn.*	Llandudno	2·56	76
,,	Sherborne St. John ...	·44	13	*Angl.*	Llanerchymedd	3·83	85
Herts.	Royston, Therfield Rec.	·41	15	*I. Man*	Douglas, Borough Cem.	4·18	92
Bucks.	Slough, Upton	·48	17	*Wigtown*	Port William, Monreith	3·60	91
Oxford	Oxford, Radcliffe ...	·50	17	*Dumf.*	Dumfries, Crichton R.I.	2·55	65
N'hants.	Wellingboro', Swanspool	·60	24	,,	Eskdalemuir Obsy. ...	4·66	86
Essex	Shoeburyness	·26	11	*Roxb.*	Kelso, Floors	1·50	52
,,	Dovercourt	·31	13	*Peebles*	Stobo Castle	2·91	84
Suffolk	Lowestoft Sec. School ...	1·24	44	*Berwick*	Marchmont House ...	1·69	44
,,	Bury St. Ed., Westley H.	·47	17	*E. Loth.*	North Berwick Res. ...	1·71	58
Norfolk	Sandringham Ho. Gdns.	1·36	45	*Midl'n.*	Edinburgh, Blackf'd. H.	2·07	76
Wilts.	Bishops Cannings ...	·83	25	*Lanark*	Hamilton W. W., T'nhill	3·13	96
Dorset	Creech Grange... ...	1·50	29	*Ayr*	Colmonell, Knockdolian	4·63	104
,,	Beaminster, East St. ...	1·65	37	,,	Glen Afton, Ayr San ...	5·15	101
Devon	Teignmouth, Den Gdns.	1·32	34	*Bute*	Rothesay, Ardencraig ...	7·35	167
,,	Cullompton	2·06	50	*Argyll*	L. Sunart, Glenborrodale	...	...
,,	Ilfracombe	2·17	48	,,	Poltalloch	6·32	[illegible]
,,	Okehampton, Uplands	1·93	32	,,	Inveraray Castle ...	11·16	159
Cornwall	Bude, School House ...	2·30	57	,,	Islay, Eallabus	7·04	148
,,	Penzance, Morrab Gdns.	2·40	52	,,	Tiree	6·90	151
,,	St. Austell	2·61	50	*Kinross*	Loch Leven Sluice ...	3·02	80
,,	Scilly, Tresco Abbey ...	2·64	69	*Fife*	Leuchars Airfield ...	1·58	61
Glos.	Cirencester	·86	26	*Perth*	Loch Dhu	9·32	190
Salop	Church Stretton ...	1·62	44	,,	Crieff, Strathearn Hyd.	2·73	69
,,	Cheswardine Hall ...	...	...	,,	Pitlochry, Fincastle ...	2·31	71
Worcs.	Malvern, Free Library	·85	29	*Angus*	Montrose, Sunnyside ...	1·34	49
Warwick	Birmingham, Edgbaston	·79	28	*Aberd.*	Braemar	2·02	54
Leics.	Thornton Reservoir ...	·89	32	,,	Dyce, Craibstone ...	2·02	60
Lincs.	Boston, Skirbeck ...	·93	34	,,	Fyvie Castle	1·25	33
,,	Skegness, Marine Gdns.	·97	35	*Moray*	Gordon Castle	1·08	34
Notts.	Mansfield, Carr Bank ...	·89	29	*Nairn*	Nairn, Achareidh ...	1·11	40
Derby	Buxton, Terrace Slopes	3·02	61	*Inverness*	Loch Ness, Garthbeg ...	4·10	115
Ches.	Bidston Observatory ...	2·00	61	,,	Glenquoich	16·97	170
Lancs.	Manchester, Whit. Park	2·40	73	,,	Fort William, Teviot ...	11·51	[illegible]
,,	Stonyhurst College ...	3·84	86	,,	Skye, Duntuilm ...	5·74	105
,,	Squires Gate	2·57	73	*R. & C.*	Tain, Tarlogie House ...	1·58	57
Yorks.	Wakefield, Clarence Pk.	1·10	38	,,	Inverbroom, Glackour...	6·69	119
,,	Hull, Pearson Park ...	1·10	37	,,	Applecross Gardens ...	6·66	[illegible]
,,	Felixkirk, Mt. St. John	1·10	38	,,	Achnashellach	10·03	[illegible]
,,	York Museum	1·20	45	,,	Stornoway Airfield ...	4·37	[illegible]
,,	Scarborough	1·23	39	*Suth.*	Loch More, Achfary ...	10·40	[illegible]
,,	Middlesbrough... ...	1·00	33	*Caith.*	Wick Airfield	1·75	[illegible]
,,	Baldersdale, Hury Res.	2·62	66	*Shetland*	Lerwick Observatory ...	6·13	[illegible]
Norl'd.	Newcastle, Leazes Pk....	·89	29	*Ferm.*	Crom Castle	2·98	[illegible]
,,	Bellingham, High Green	2·70	69	*Armagh*	Armagh Observatory ...	3·63	[illegible]
,,	Lilburn Tower Gdns. ...	1·74	47	*Down*	Seaforde	...	[illegible]
Cumb.	Geltsdale	3·02	81	*Antrim*	Aldergrove Airfield ...	2·71	[illegible]
,,	Keswick, High Hill ...	5·66	101	,,	Ballymena, Harryville...	3·51	[illegible]
,,	Ravenglass, The Grove	3·26	75	*L'derry*	Garvagh, Moneydig ...	4·43	[illegible]
Mon.	Abergavenny, Larchfield	1·61	38	,,	Londonderry, Creggan	4·30	[illegible]
Glam.	Ystalyfera, Wern House	5·17	75	*Tyrone*	Omagh, Edenfel ...	4·22	[illegible]

In.	Per cent. of In.
1·78	37
...	...
3·45	[illegible]
3·54	54
5·01	[illegible]
1·66	114
2·56	76
3·83	[illegible]
4·18	[illegible]
3·60	[illegible]
2·55	65
4·66	[illegible]
1·50	52
2·91	84
1·69	44
1·71	[illegible]
2·07	76
3·13	96
4·63	104
5·15	101
7·35	[illegible]
...	...
6·32	[illegible]
1·16	[illegible]
7·04	[illegible]
6·90	151
3·02	[illegible]
1·58	61
9·32	[illegible]
2·73	[illegible]
2·31	71
1·34	[illegible]
2·02	54
2·02	60
1·25	33
1·08	34
1·11	[illegible]
4·10	115
6·97	170
1·51	[illegible]
5·74	105
1·58	57
6·69	[illegible]
6·66	[illegible]
10·03	[illegible]
4·37	[illegible]
10·40	[illegible]
1·75	[illegible]
6·13	[illegible]
2·98	[illegible]
3·63	[illegible]
...	...
2·71	[illegible]
3·51	[illegible]
4·43	[illegible]
4·30	[illegible]
4·22	[illegible]